The Japan Society for Precision Engineering

Introduction of JSPE Best Paper Awards 2018

1. A two-degree-of-freedom micro electromagnetic actuator utilizing a fine pitch and multi-pole magnetized permanent magnet

Noriei AZUMA, Shunya TANAKA, Ryogen FUJIWARA, Tadahiko SHINSHI and Kenichi SUZUKI

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Aiming the use in an optical image stabilizer for smartphone cameras, a two-degree-of-freedom microactuator consisting of a thin permanent magnet having a fine pitch chessboard magnetic pattern, a two-layer printed-coil, and a silicon elastic guideway was proposed and fabricated. The permanent magnet of 9.1 x 9.1 x t 0.5 mm was processed by wire electric discharge machining to minimize the damage of the magnetic properties. The permanent magnet with lattice-patterned grooves for thermal insulation was multi-pole-magnetized by laser assisted heating. The elastic guideway was machined using deep reactive ion etching. The driving forces of 1.24 and 1.66 mN and the positioning ranges of 211 and 282 μm in the X and Y directions, respectively, were obtained with a coil current of ±0.1 A in each layer coil.

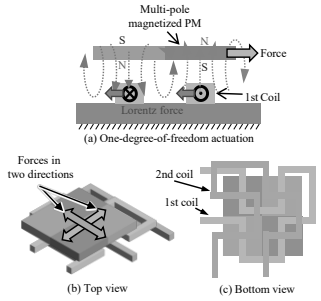

Fig. 1. Principle of two-degree-of-freedom actuation.

2. Investigation of the effect of grain size variation on ground wafer surface by grinding experiment/simulation

Yutaro EBINA, Tomohiro MAEZAKI, Libo ZHOU, Jun SHIMIZU, Teppei ONUKI, Hirotaka OJIMA and Masatomo INUI

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The grinding wheel is comprised of three elements; abrasive grain, bonding material, and pore, which are specified by five factors; type of abrasive grain, grain size, type of bonding material, grade of hardness and abrasive grain volume percentage. Regarding the abrasive grain, it is well known that shape and number of cutting edge significantly effects grinding performance such as surface roughness, grinding force and grinding wheel life. In general, abrasive grain size is determined by the mean diameter of abrasive grain. However, the abrasive grains in a grinding wheel are randomly oriented and irregular in size and shape. There is no particular aspect to regulate the grain size variation in JIS (Japanese Industrial Standards). This paper investigates the effect of grain size variation on the ground surface topography by actual grinding on silicon wafers and analysis based on grinding simulation. The results reveal that the standard deviation of grain size is a very important index to characterize the grinding performance of a wheel. Smaller standard deviation leads to larger density of effective cutting-edge under the same volume percentage of abrasive grain contained in the wheel. This fact significantly contributes to not only achieve a better surface roughness and more uniform surface integrity, but also shorten the finishing time.

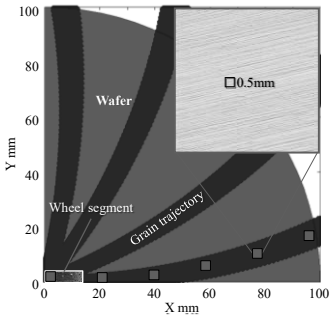

Fig. 2. Cutting path and measurement point.

3. One-shot stereolithography for biomimetic micro hemisphere covered with relief structure

Yuki SUZUKI, Kunikazu SUZUKI, Masaki MICHIHATA, Kiyoshi TAKAMASU and Satoru TAKAHASHI

Precision Engineering, Vol. 54, pp. 353-360

Biomimetic micro-structured surfaces have been attracting attention in recent years owing to their features, including optical reactivity, wetting property, and sliding property. One of the typical features of these functional structures is that densely arrayed dual-scale structures are present, such as several tens of micrometers of a hemisphere-like form covered with many several micrometer protrusions on the surface. A dual-scale structure similar to this is difficult to quickly and cheaply fabricate using existing methods: Semiconductor process, Micro-stereolithography, and focused ion beam. In this research, a novel technique to fabricate a biomimetic hemisphere-like form covered with a relief structure is proposed. It utilizes the difference between the refractive indexes of two materials and the focusing cone-shaped light with a solid angle, which includes the critical angle formed when light enters from a side where the refractive index is higher than that of the other. In this situation, the refracted light radially expands. Thus, when the low-refractive-index medium is a photocurable resin, it is cured into a hemisphere-like form. In addition, properly

modulating the light-intensity distribution of the incident light allows us to create many protrusions, such as a relief structure on the hemisphere surface. In this research, a theoretical model was constructed, and the proposed method was verified by simulation using Snell's law and the Lambert–Beer law. Moreover, the apparatus to realize the proposed method was developed, and we practically verified that this method can fabricate a dual-scale structure such as a hemisphere-like form covered with a relief structure.

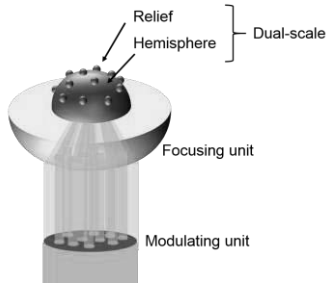

Fig. 3. Conceptual figure of the proposed one-shot stereolithography that combines the focusing and modulating units. The modulated light enters the focusing unit and exposes the photocurable resin. A form corresponding to the light-intensity distribution is fabricated.

Introduction of JSPE Numata Memorial Paper Awards 2018

1. Sensor-less on-line chatter detection in turning process based on phase monitoring using power factor theory

Shuntaro YAMATO, Takayuki HIRANO, Yuki YAMADA, Ryo KOIKE and Yasuhiro KAKINUMA

Precision Engineering, Vol. 51, pp. 103-116

This paper presents a sensor-less on-line chatter detection method for a turning process by introducing a mechanical energy factor (MEF) and a mechanical power factor (MPF). The MEF and MPF serve as indexes for self-excited chatter and forced chatter, respectively. The indexes are based on the power-factor theory, which generally represents the electrical-power efficiency as having a correlation with the phase difference between the current and the voltage. By applying this theory to a mechanical system, the MEF and MPF can be employed to monitor the phase difference between the cutting force and the displacement/velocity of the tool system, respectively. By monitoring the phase difference, chatter vibration can be detected in the time domain with a high response and small number of computations. The MEF and MPF can be calculated without using additional external sensors employing the sensor-less cutting-force estimation technique based on the disturbance observer. The monitoring performance of the proposed method was evaluated through several outside turning tests with a prototype precision lathe. The results showed that both the self-excited and forced chatters were successfully detected with unique thresholds, which did not depend on the cutting condition or the workpiece material.

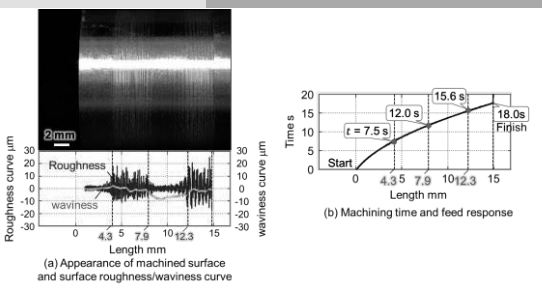

Fig. 4. Machined surface and machining time in machining test with respect to increasing spindle rotation speed.

2. Design and testing of a compact non-orthogonal two-axis Lloyd's mirror interferometer for fabrication of large-area two-dimensional scale gratings

Yuki SHIMIZU, Ryo AIHARA, Kazuki MANO, Chong CHEN, Yuan-Liu CHEN, Xiuguo CHEN and Wei GAO

Precision Engineering, Vol. 52, pp. 138-151

A compact and stable two-axis Lloyd's mirror interferometer based on a new non-orthogonal type of mirror-substrate assembly is designed for the fabrication of 100 mm × 100 mm large-area two-dimensional (2D) diffraction scale gratings in a research laboratory or a small-scale manufacturing facility. At first, the required mirror sizes used in the new non-orthogonal type and the conventional orthogonal type are compared based on the geometrical analysis. It is identified that the width of the mirror can be reduced to half in the non-orthogonal type while the required mirror height and the expanded laser beam diameter are comparable to those in the orthogonal type. The shorter mirror width makes it possible to design a compact mirror-substrate assembly so that the overall interferometer can be realized in an overall size of 1480 mm × 730 mm for mounting on a commercially available general-purpose 1500 mm × 1000 mm vibration isolation table for use in research laboratories. It is then verified by the simulation that the selected laser source and the designed beam expansion assembly, which are the other main parts of the interferometer, are effective for fabricating the designed grating structures. Experiments are also carried out to demonstrate the feasibility of the constructed interferometer for fabricating 100 mm × 100 mm 2D scale gratings with a short period of 1 μm.

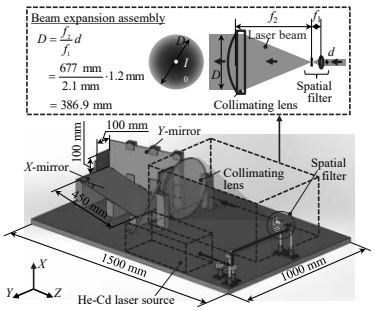

Fig. 5. Schematic of the developed optical setup of the compact non-orthogonal two-axis Lloyd's mirror interferometer for fabrication of large area 2D scale gratings.